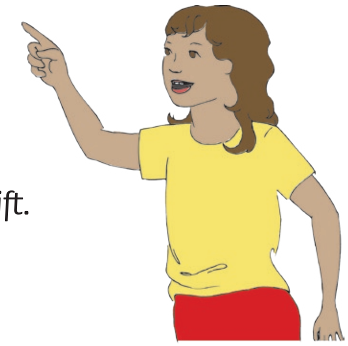
Exploration 7:
Rotor Blade Weight and Flight



Students investigate how a rotor blades' weight affects its ability to generate lift.

Main Concept

People can often learn about things by doing something to the things and noting what happens.

Goal

Students will design and construct simple models and use them to conduct a scientific investigation into how the material from which a rotor blade is made affects the amount of lift it generates.

Objectives and Standards

Objectives	Standards
1. Students will design and construct simple models that use rotor blades of different weights or rotor blades made from differently weighted materials for flight. (For example, lightweight paper vs. cardstock vs. cardboard vs. plastic vs. aluminum foil, etc.) 2. Students will conduct an investigation in rotorcraft flight using the models they construct. 3. Students will differentiate between the flight of a model using one type of rotor blade material/weight and the flight of a model using a different type of rotor blade material/weight. (For example, lightweight paper vs. cardstock vs. cardboard vs. plastic vs. aluminum foil, etc.) 4. Students will develop the ability to do scientific inquiry. 5) Students will develop an understanding of scientific inquiry. 6) Students will work collaboratively with a team and share their findings.	**Partially Meets:** 2061: 1B (K-2) #1 2061: 1C (K-2) #2 2061: 1B (3-5) #1 NSES: A (K-4) #1, #2 **Addresses**: 2061: 4F (3-5) #1

Prerequisite Concepts

- *A model of a rotorcraft can be used to test how a rotorcraft flies.*
- *The rotor blades on a rotorcraft spin and provide the force to lift the rotorcraft.*
- *Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be.*

Links to Resources that Address Prerequisite Concepts

Robin Whirlybird Exploration #1: What is a Model?
Robin Whirlybird Exploration #2: How Do Rotorcraft Fly?
Robin Whirlybird Exploration #3: How Do Rotors Create Lift?
Robin Whirlybird Exploration #4: Rotorcraft Flight and Lift
Robin Whirlybird Exploration #5: Rotor Blade Shape and Flight
Robin Whirlybird Exploration #6: Long and Short Rotor Blades

Robin Whirlybird
http://rotored.arc.nasa.gov/story/robin18.html
http://rotored.arc.nasa.gov/story/robin3.html
Click on button "Rotorcraft Activities"

New Concepts

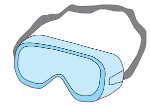
- *Scientific inquiry involves learning about things by doing something to the things and noting what happens.*

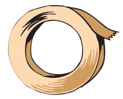
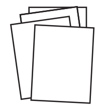
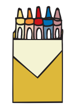
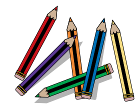
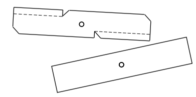
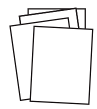
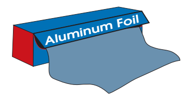
- *Scientific investigations may take many different forms, including observing what things are like or what is happening somewhere, collecting specimens for analysis, and doing experiments. Investigations can focus on physical, biological, and social questions.*

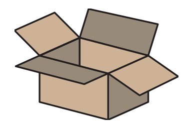
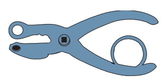
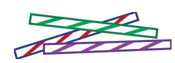
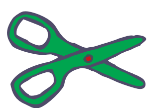
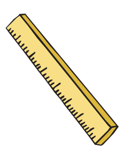
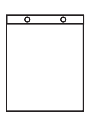
Schedule

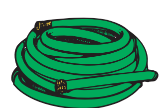
Allow 2-3 sessions of 20-40 minutes.

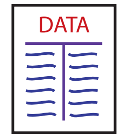
Materials

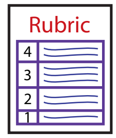
- Protective eyewear for each student, available from most school science supply stores and catalogs 
- Chalk or tape 

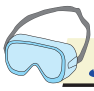

- Drawing paper and crayons or coloring pencils   
- Template for rotor blades preferably of the students' design 
- Paper of various weights, heavy aluminum foil, and cardboard of various weights  


- Student-stipulated materials from which students will construct rotor blades based upon their own designs
- Hole punchers 1 per team/pair 
- Sturdy plastic drinking straws (approximately 3 straws per team/pair) 
- Scissors 1 per team/pair 
- Cellophane tape roll 1 per team/pair 
- Rulers 1 per team/pair 
- Chart paper 
- Stopwatches or watch/clock with second-hand 

- Two, 1-foot long pieces of rubber tubing or a rubber hose of varying flexibility from soft to stiff 

- A small section of large link, heavy-duty chain 
- At least one Data Table (in this exploration's appendix) for each team/pair 

- Evaluation rubric in this exploration's appendix 



Safety Precautions

When using flying objects in a classroom, post very strict rules and review them with the students. All students MUST wear protective eyewear while any object is in flight. Clearly delineate one or more staging areas, preferably with students' input. Mark on the ground with chalk or tape, where all "test flights" will take place. Caution students to "secure the area" before beginning any "test flight."

Engage

1. Draw on students' prior knowledge of rotorcraft by asking them:
   - What do rotorcraft need so they can fly?
   - What have you discovered about how a rotor blade's length affects the rotorcraft's flight?
2. Ask students what sort of a model they would use to investigate the effect of a rotor blade's weight on the rotorcraft's flight. Students may choose the type of model they used in Exploration #5 and Exploration #6, or choose a different design altogether.
3. Distribute drawing paper and crayons or colored pencils so students can draw their designs.
4. Engage students in the design process either as a whole class, in teams, or in pairs.
   - Have each team or pair present their design to the class.
   - Follow up each short presentation with a brief discussion as to the design's viability.
   - Students can choose to put all their design ideas together into one really good idea or agree to use one or two of the more viable designs.

5. Have students construct their rotor blades, cutting out the shapes in the material of their choosing, and taping the rotors to the straws.

6. Once the models are constructed proceed to the next section.

Explore

1. **Question**: Using our model, how can we find out if there is a difference in the way the model flies using a heavyweight rotor blade or a lightweight rotor blade?

2. Ask students, in their teams or with partners, to draw out step-by-step how they would set up a test to verify each rotor blade’s flight.

3. Have students share their experiment ideas with the class.

4. Discuss each proposed experiment.

5. Have students help each team make revisions in their experiment design by asking questions about “how it will work.”

6. Give each team time to revise their experiments.

7. Have the teams share their revised experiment ideas again with the class. After discussing all the proposed experiments, decide if only one test should be developed from all the good ideas or whether each team should go ahead with their own.

8. **Question**: What do you think you might find out?
   Record and post their hypotheses on chart paper.

9. **Question**: How can we make this a fair test?
   - Solicit ideas and direct students’ focus toward holding the model the same distance from the ground each time, testing in an area without moving air, the number of times they should perform each test, as well as the rotation rate of the rotor blades. Have the group come to consensus on these test factors.

   Note to Teacher: This would be a “fair test” if the heavyweight rotor and the lightweight rotor are the same shape, length and width, carry the same “load” (or weight), have the same “fuselage” (the drinking straw), and are flown under the same conditions.

10. Discuss safety issues. Constantly monitor safety and the proper use of materials.

11. Emphasize proper observation skills and the importance of “thinking aloud.”

12. Allow 10 minutes for open explorations. As you circulate through the group, record students’ observations, actions, ideas and questions.

Explain

1. Have students draw a picture that depicts the results of their rotor blade experiments and each model’s flight.
   - Gather students’ data, perhaps regarding length of time each rotor flew.
   - Record the data in a table like the Data Table in this exploration’s appendix. The left column of the table can be used to indicate the weight of the blade, and the right column to list the amount of time the rotorcraft stayed aloft.
   - Ask the class to decide how this data could be depicted. (For example, a bar graph, line graph or pictograph.)

2. Gather students together for a discussion. Reflect upon the questions the students raised based upon your own classroom observations during their exploration time.

3. Ask the group to draw a conclusion about the rotor blades’ weight and its flight performance.

   Note to Teacher: In a fair test in which differently weighted rotor blades are made in the same shape, length, and width are flown under the same conditions and carry the same “load” (or weight), the results will depend upon the materials used. Students will find that with the “fuselage” weight and the rotor blade shape constant, a continuum will emerge in which lighter weight rotor blades will generate less lift than heavyweight rotor blades, but only up to a certain weight. After a certain weight, the rotor blades will be too heavy for the “fuselage” and the students will NOT be able to spin the rotor fast enough to generate lift. Line up the blades from lightest to heaviest. With this added data, the results can be graphed and students will clearly see the progression or continuum. What should emerge for the students will be the concept that heavier is not always “better.” In terms of design, rotor blades need to be constructed from materials that are strong and stiff enough to maintain their shape during the spinning motion in order to generate lift. Students will notice that the lightweight paper that “droops too much” will not be capable of generating much lift. However, in the aviation world, the rotor blades on rotorcraft do need some flexibility in order to withstand the stresses of flight. This is why when a helicopter is at rest, the rotor blades droop toward the ground and when the rotor blades spin the tips actually bend upward. That’s how strong, yet flexible the material has to be.

4. Show students their hypothesis and compare the hypothesis with the conclusion. Ask students how their original hypothesis should be changed.

Extend

1. Bring 2 one-foot long pieces of rubber tubing or a rubber hose. Have one be highly flexible and the other quite stiff.

2. Pass these around to the students and then have the class give the characteristics of each.

Hose #1	**Hose #2**
Bendable/flexible	Stiff
Color	Color
Texture	Texture
Material	Material

3. Note these characteristics on large size paper or the front board. See the box for topics.

4. Ask students to think of everyday objects/tools they have around their house.

5. Create a list of two columns, one titled flexible/bendable objects and the other titled stiff or inflexible.

6. Ask students to place the objects they thought of into one of the two categories. Review each one, noting the materials from which it is formed (plastic, metal, rubber, wood) and ask whether this tool would work as well if it were NOT flexible or stiff.

Flexible / Bendable	**Stiff / Inflexible**
Garden hose	Mop handle
Bristles on a broom or hand brush	screwdriver
Electrical cord	Pencil
Rope	Large Mixing spoon

6. Hold up a large link heavy-duty chain and ask in which category it should be placed. Ask the reasoning for their categorization.
Note to Teacher: A chain has both properties; each link is stiff, yet when linked together all the links work in a more flexible way.

7. Ask students in their teams to design a tool that can be used to dust the ceiling fans that hang 20 feet above the floor. How flexible should the tool be? Would it have the same amount of flexibility throughout? Would the handle be made out of different materials from the part that dusts the fans?

8. Have each group share their design and their reasons for their design.

Evaluate

Use the rubric in this exploration's appendix and evaluate students on the following:

1. *Rotor blade design and construction of the rotorcraft model*
   Students can also use the rotor blade design in the appendix to construct their models.

2. *Investigation*
   - *Students should carry out the investigation with a partner or a team.*
   - *They conduct a "fair test" and collect and record data.*

3. *Reaching a conclusion*
   Students reach a conclusion based on their data.

4. *Revise hypothesis*
   Students revise their hypothesis based on their data.

Further Exploration

- *Students might have additional questions regarding the connection between how fast the rotor blades turn with how long the rotorcraft stays in the air, how high it flies, fast it flies, or if long rotor blades can fly with more weight than short rotor blades.*

- *Another exploration could arise from questions about how combining these factors (such as length and width of rotor blades, weight of rotor blades, AND weight of fuselage/model) affect lift.*

- *Another exploration could arise from a question about rotorcraft design. Are rotorcraft designed to perform certain tasks? If so, would the shape and length of the rotor blades make lift better or worse?*

- *If time and interest permits transform students' ideas, questions, observations, and hypotheses into additional investigations.*

Exploration 7:
Rotor Blade Weight and Flight

Data Table

Team Members:

____________________ ____________________

____________________ ____________________

Use this table to record your observations. Draw or describe the rotor blade.

Rotor Blade Weight/Material	Time

Exploration 7: Rotor Blade Weight and Flight Rubric

Students investigate how a rotor blades' weight affects its ability to generate lift.

Evaluate students' work using the following rubric:

4	• Good, clear design of rotorcraft model • Well-constructed rotorcraft model • Use of "fair testing" with one variable changed at a time • Data recorded clearly • Reached reasonable conclusion based on tests and observations • Revised hypothesis • Good exchange of ideas and collaborative teamwork
3	• Clear design of rotorcraft model • Adequately constructed rotorcraft model • Use of "fair testing" with one variable changed at a time • Data recorded but not organized clearly • Reach reasonable conclusion based on tests and observations • Revised hypothesis • Some exchange of ideas and collaborative teamwork
2	• Attempt to design of rotorcraft model • Rotorcraft model constructed but inadequate for test • Attempt to use "fair testing" with one variable changed at a time • Data recorded • Reach conclusion based on some tests • Attempted to revise hypothesis • Little exchange of ideas and collaborative teamwork
1	• Little attempt to design of rotorcraft model • Attempt to construct rotorcraft model • Limited understanding and use of "fair testing" • Little or no data recorded • Conclusion not reached or not based on tests • Did not adequately revise hypothesis • Limited exchange of ideas and collaborative teamwork